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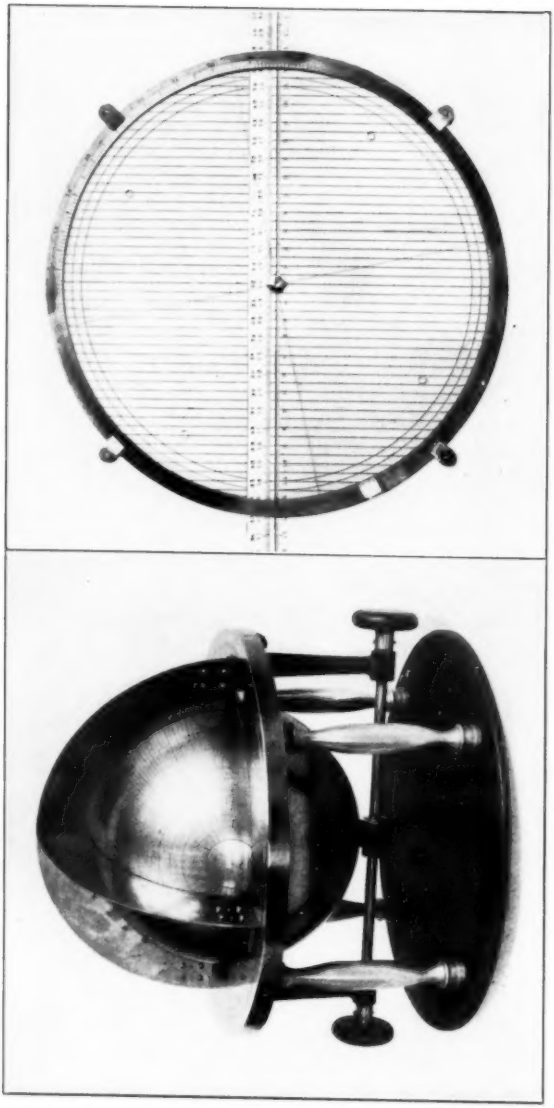
PLATE VIII



INSTRUMENTS FOR ASSISTING IN THE REDUCTION OF SOLAR OBSERVATIONS

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THE DETERMINATION OF HELIOGRAPHIC POSITIONS AND THE COMPONENTS OF THE VELOCITIES INVOLVED IN SOLAR SPECTROSCOPY, EMPLOYING TABLES AND MECHANICAL DEVICES

By RALPH E. DELURY

(With Plate VIII)

TABLES and mechanical devices used at Ottawa[1] lessen greatly the time required in determining the heliographic co-ordinates and the components of velocity of the solar and terrestrial rotations, and the orbital revolution of the earth, especially as many of the Ottawa observations include spectra of seven points on the solar disc photographed simultaneously. The ordinary logarithmic method of making the computations requires a prohibitive time for such observations. A brief description of the tables and mechanisms to supplement them is given herewith.

HELIOGRAPHIC POSITIONS

The heliographic latitude B_o of the centre of the solar disc is derived from the equation,

$$\sin B_o = \sin I \sin(\odot - N) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where I is the inclination of the solar axis to the ecliptic and N is the longitude of the ascending node on the solar equator; and according to Carrington's determinations from observations of the solar spots, 1853-1861,

$$I = 7^\circ\ 15', \text{ and } N = 73^\circ\ 40' \text{ for } 1850.0.$$

This adopted position of the solar axis agrees within about 0°.1 with

[1]Publications of the Dominion Observatory, Vol. VI, Part I, Sections 7, 8, 9

that derived by the Maunders from an extensive series of Greenwich photographs of sunspots.

The angle P, between the projected solar and terrestrial axes on the solar disc, is determined from the angles p and p' respectively between these projected axes and the normal to the ecliptic, which are computed from the equations,

$$\tan p = \tan I \cos (\odot - N) \quad \ldots\ldots (2)$$

$$\tan p' = \tan \epsilon \cos \odot \quad \ldots\ldots (3)$$

or

$$\cos p = \cos I \sec B_o \quad \ldots\ldots (2a)$$

$$\cos p' = \cos \epsilon \sec \delta \quad \ldots\ldots (3a)$$

where ϵ is the obliquity of the ecliptic and δ the declination of the sun.

Daily values of B_o and P are now tabulated in *The Nautical Almanac* and in *The American Ephemeris and Nautical Almanac*.

In observing, the "equatorial diameter" of the solar disc is set P from the "east-west line" determined from the direction of drifting of the solar image.

A table of values of p for the range 7°.25 in the values of B_o, has been computed from equation (2a) so that the angle between the equatorial diameter of the solar disc and the ecliptic line may be easily read.

The position of an observed point on the solar disc is recorded by measuring α, the position-angle between the equatorial diameter and the radius of the disc on which the point lies, and r, the distance of the point from the centre of the disc along that radius expressed as a decimal of the radius.

The heliocentric angle ρ, between observer and observed point, may be computed from the equation,

$$\rho = \sin^{-1} r - rs \quad \ldots\ldots (4)$$

where s is the angular semi-diameter of the sun. In 1878 Warren de la Rue issued a useful table of values of Log cos ρ and Log sin ρ for values of r progressing by thousandths of the radius from centre to limb of the disc. From this has been derived a table of values of ρ corresponding to values of r with sufficient intervals for exact reading.

The heliographic latitude ϕ is computed from the equation,

$$\sin \phi = \sin B_o \cos \rho + \cos B_o \sin \rho \sin \alpha \quad \ldots\ldots (5)$$

For this computation, tables have been calculated in terms of r and B_o, of the products, $\sin B_o \cos \rho$ and $\cos B_o \sin \rho$, which include also values of $\cos \rho$ and $\sin \rho$ respectively. Multiplication by $\sin a$ is performed by machine.

The heliographic longitude λ, measured from the plane containing the axis of the sun and the radius vector, is computed from the equation,

$$\sin \lambda = \sin \rho \cos a \sec \phi \quad \ldots\ldots (6)$$

For this computation a table of values of the product $\cos a \sec \phi$ has been calculated. In this table the values of a progress by increments of 5°, standard for the usual observations of the solar rotation, and the values of ϕ by increments varying from 1° to 0°.1 to insure sufficiently accurate interpolation over the range of possible values of ϕ for each value of a, the maximum values of ϕ occurring at the values of ρ in the equation,

$$\tan \rho = \cot 7°.25 \sin a \quad \ldots\ldots (7)$$

Components of Velocity

Solar Rotation.—The angle γ_o, between the radius vector and the pole of the plane containing the solar axis and the observed point, may be determined from the equation,

$$\cos \gamma_o = \cos B_o \sin \lambda \quad \ldots\ldots (8)$$
$$= \cos B_o \sin \rho \cos a \sec \phi \quad \ldots\ldots (9)$$

and is readily computed by multiplying by machine the selected values of $\cos B_o \sin \rho$ and $\cos a \sec \phi$ from the tables mentioned above; or by multiplying $\cos B_o$ by $\sin \lambda$ when for other purposes the latter has been derived.

Since s, the angular semi-diameter of the sun, is about 16′, the angle γ_o is approximately the angle between the direction of the solar rotation at the observed point and the "line-of-sight". The exact angle γ, namely the angle between the pole of the plane containing the solar axis and the observed point and the line from the observer to the observed point, may be computed from the equation,

$$\cos \gamma = \cos (B_o \pm rs \sin a) \sin (\lambda + rs \cos a) \quad \ldots\ldots (10)$$

where $B_o+rs \sin a$ applies to points in the half of the solar disc containing the equator, and $B_o-rs \sin a$ to points in the other half.

The component to the observer of the velocity V, of the sun's rotation at the observed point is,

$$V \cos \gamma \ldots\ldots\ldots\

0.002342 $d\odot$ km. per sec. ($d\odot$ in minutes per day)
or, 0.000937 $d\odot$ km. per sec. ($d\odot$ in seconds per hr.)

A table was computed of this for the range in values of $d\odot$ per day and per hour.

Another table of the differences between components of the earth's orbital velocity to solar centre and points on the limb situated β from the ecliptic, β progressing by intervals of 2° from 0° to 88°, and $d\odot$ in seconds per hour at intervals of 1″ from 143″ to 153″.

Since the velocity to the centre of the sun, dR/dt, can be found from the almanacs, the component of the orbital velocity of the earth to any point on the solar disc at position-angle β from the ecliptic and distant r from the centre of the solar disc, namely,

$$dR/dt \pm 0.000937\ r \cos \beta\ .\ d\odot \text{ km. per sec.},$$

can be readily determined with the help of the latter table.

The angle i may be computed from the equation,

$$\cot i = e^{-1} \operatorname{cosec} u + \cot u,$$

where e is the eccentricity of the earth's orbit and u the true anomaly. A table of values of i was computed for each degree of value of u. The greatest value of i is 57′.56 when cos u is $-e$, at which times s is 16′.03, so that a point on the sun is at most about 73′.6 from the normal to the direction of the orbital motion of the earth. This angle is so small that the computation of the orbital velocity components to points on the disc may be reduced to linear graphical measurement. For this purpose the following apparatus was made.

The device, illustrated herewith (Plate VIII), consists essentially of a graduated scale representing the ecliptic line, its zero corresponding to the centre of the solar disc; a position-angle ring, graduated in degrees, which may be rotated about this centre; and a concentric disc of transparent film which may be rotated to any position-angle α on the ring after the 0° of the latter is set p° from the ecliptic line. Points on the transparent film corresponding to observed points are read in projection on the scale and converted into km. per sec., representing components relative to the centre, by multiplication by the factor derived from the

tables. A sliding scale moved parallel to the ecliptic scale to a reading equivalent to dR/dt yields readings equivalent to the components of the orbital velocity to the observed points.

A Graduated Sphere and Co-Ordinate Frame for Reading ϕ, λ, γ_o and γ

The instrument shown in Plate VIII consists of a spherical shell 228 mm. in diameter, graduated in degrees of latitude and every 2° of longitude, capable of rotation on an axis through the equatorial plane and surmounted by a co-ordinate frame which may be rotated in the plane containing that axis on a ring inset in the plane supporting the axis. The rotating ring and co-ordinate plates are graduated in degrees.

To make readings, the polar axis of the sphere is tilted angle B_o by means of the friction disc which partly supports the weight of the sphere, the position-angle ring is rotated angle α from the equator, and the values of ρ corresponding to the various observed points, read from the table, are used as "pointers" on the co-ordinate plates for reading ϕ and λ for each observed point. At the higher latitudes the readings of λ may not be exact enough and supplementary values may be derived from the tables. The angle γ_o is easily read on one of the co-ordinate plates as the highest angle above the position-angle plane to which the λ line ascends when the co-ordinate frame is rotated. From this value γ may be derived with the help of the tables or it may be read directly, as γ_o was read, by substituting for B_o and λ the values of these given in equation (10).

The sphere greatly lessens the time of the determinations, and the readings with the aid of a magnifier are usually within 0°.1 of the computed values. It is particularly valuable for the multiple-point observations (distributed on the edges of the two co-ordinate plates) for which readings may be made with the pair of settings of B_o and α. It may, of course, be applied to numerous other astronomical problems using a polar axis as well.

Dominion Observatory,
Ottawa, Canada.
September, 1934

THE NEW WORLD-PICTURE OF MODERN PHYSICS*

By Sir James Hopwood Jeans

IT is a full half-century since this chair was last occupied by a theoretical physicist in the person of the late Lord Rayleigh. In that interval the main edifice of science has grown almost beyond recognition, increasing in extent, dignity and beauty, as whole armies of labourers have patiently added wing after wing, story upon story and pinnacle to pinnacle. Yet the theoretical physicist must admit that his own department looks like nothing so much as a building which has been brought down in ruins by a succession of earthquake shocks.

The earthquake shocks were, of course, new facts of observation, and the building fell because it was not built on the solid rock of ascertained fact, but on the ever-shifting sands of conjecture and speculation. Indeed it was little more than a museum of models, which had accumulated because the old-fashioned physicist had a passion for trying to liken the ingredients of nature to familiar objects such as billiard-balls, jellies and spinning tops. While he believed and proclaimed that nature had existed and gone her way for countless eons before man came to spy on her, he assumed that the latest newcomer on the scene, the mind which could never get outside itself and its own sensations would find things within its limited experience to explain what had existed from all eternity. It was expecting too much of nature, as the ruin of our building has shown. She is not so accommodating as this to the limitations of the human mind; her truths can only be made comprehensible in the form of parables.

Yet no parable can remain true throughout its whole range to the facts it is trying to explain. Somewhere or other it must be too wide or too narrow, so that "the truth, the whole truth, and nothing

*Portion of the presidential address to the British Association for the Advancement of Science at Aberdeen on September 5, 1934.

but the truth" is not to be conveyed by parables. The fundamental mistake of the old-fashioned physicist was that he failed to distinguish between the half-truths of parables and the literal truth.

Perhaps his mistake was pardonable, perhaps it was even natural. Modern psychologists make great use of what they describe as "word-association." They shoot a word at you, and ask you to reply immediately with the first idea it evokes in your uncontrolled mind. If the psychologist says "wave," the boy scout will probably say "flag," while the sailor may say "sea," the musician "sound," the engineer "compression" and the mathematician "sine" or "cosine." Now the crux of the situation is that the number of people who will give this last response is very small. Our remote ancestors did not survive in the struggle for existence by pondering over sines and cosines, but by devising ways of killing other animals without being killed themselves. As a consequence, the brains we have inherited from them take more kindly to the concrete facts of everyday life than to abstract concepts; to particulars rather than to universals. Every child, when first it begins to learn algebra, asks in despair "But what are x, y and z?" and is satisfied when, and only when, it has been told that they are numbers of apples or pears or bananas or something such. In the same way, the old-fashioned physicist could not rest content with x, y and z, but was always trying to express them in terms of apples or pears or bananas. Yet a simple argument will show that he can never get beyond x, y and z.

Physical science obtains its knowledge of the external world by a series of exact measurements or, more precisely, by comparisons of measurements. Typical of its knowledge is the statement that the line H_α in the hydrogen spectrum has a wave-length of so many centimetres. This is meaningless until we know what a centimetre is. The moment we are told that it is a certain fraction of the earth's radius, or of the length of a bar of platinum, or a certain multiple of the wave-length of a line in the cadmium spectrum, our knowledge becomes real, but at that same moment it also becomes purely numerical. Our minds can only be acquainted with things inside themselves—never with things outside. Thus we can never know the essential nature of anything, such as a centimetre or a wave-length, which exists in that mysterious world outside our-

selves to which our minds can never penetrate; but we can know the numerical ratio of two quantities of similar nature, no matter how incomprehensible they may both be individually.

For this reason, our knowledge of the external world must always consist of numbers, and our picture of the universe—the synthesis of our knowledge—must necessarily be mathematical in form. All the concrete details of the picture, the apples and pears and bananas, the ether and atoms and electrons, are mere clothing that we ourselves drape over our mathematical symbols—they do not belong to nature, but to the parables by which we try to make nature comprehensible. It was, I think, Kronecker who said that in arithmetic God made the integers and man made the rest; in the same spirit, we may add that in physics God made the mathematics and man made the rest.

The modern physicist does not use this language, but he accepts its implications, and divides the concepts of physics into observables and unobservables. In brief, the observables embody facts of observation, and so are purely numerical or mathematical in their content; the unobservables are the pictorial details of the parables.

The physicist wants to make his new edifice earthquake-proof—immune to the shock of new observations—and so builds only on the solid rock, and with the solid bricks, of ascertained fact. Thus he builds only with observables, and his whole edifice is one of mathematics and mathematical formulae—all else is man-made decoration.

For instance, when the undulatory theory had made it clear that light was of the nature of waves, the scientists of the day elaborated this by saying that light consisted of waves in a rigid, homogeneous ether which filled all space. The whole content of ascertained fact in this description is the one word "wave" in its strictly mathematical sense; all the rest is pictorial detail, introduced to help out the inherited limitations of our minds.

Then scientists took the pictorial details of the parable literally, and so fell into error For instance, light-waves travel in space and time jointly, but by filling space and space alone with ether, the parable seemed to make a clear-cut distinction between space and time. It even suggested that they could be separated out in practice

—by performing a Michelson-Morley experiment. Yet, as we all know, the experiment when performed only showed that such a separation is impossible; the space and time of the parable are found not to be true to the facts—they are revealed as mere stage-scenery. Neither is found to exist in its own right, but only as a way of cutting up something more comprehensive—the space-time continuum.

Thus we find that space and time can not be classified as realities of nature, and the generalized theory of relativity shows that the same is true of their product, the space-time continuum. This can be crumpled and twisted and warped as much as we please without becoming one whit less true to nature—which, of course, can only mean that it is not itself part of nature.

In this way space and time, and also their spacetime product, fall into their places as mere mental frameworks of our own construction. They are of course very important frameworks, being nothing less than the frameworks along which our minds receive their whole knowledge of the outer world. This knowledge comes to our minds in the form of messages passed on from our senses; these in turn have received them as impacts or transfers of electromagnetic momentum or energy. Now Clerk Maxwell showed that electromagnetic activity of all kinds could be depicted perfectly as traveling in space and time—this was the essential content of his electromagnetic theory of light. Thus space and time are of preponderating importance to our minds as the media through which the messages from the outer world enter the "gateways of knowledge," our senses, and in terms of which they are classified. Just as the messages which enter a telephone exchange are classified by the wires along which they arrive, so the messages which strike our senses are classified by their arrival along the space-time framework.

Physical science, assuming that each message must have had a starting-point, postulated the existence of "matter" to provide such starting-points. But the existence of this matter was a pure hypothesis; and matter is in actual fact as unobservable as the ether, Newtonian force and other unobservables which have vanished from science. Early science not only assumed matter to exist, but further pictured it as existing in space and time. Again this assumption had no adequate justification; for there is clearly no

reason why the whole material universe should be restricted to the narrow framework along which messages strike our senses. To illustrate by an analogy, the earthquake waves which damage our houses travel along the surface of the ground, but we have no right to assume that they originate in the surface of the ground; we know, on the contrary, that they originate deep down in the earth's interior.

The Newtonian mechanics, however, having endowed space and time with real objective existences, assumed that the whole universe existed within the limits of space and time. Even more characteristic of it was the doctrine of "mechanistic determinism" which could be evolved from it by strictly logical processes. This reduced the whole physical universe to a vast machine in which each cog, shaft and thrust bar could only transmit what it received, and wait for what was to come next. When it was found that the human body consisted of nothing beyond commonplace atoms and molecules, the human race also seemed to be reduced to cogs in the wheel, and, in face of the inexorable movements of the machine, human effort, initiative and ambition seemed to become meaningless illusions. Our minds were left with no more power or initiative than a sensitized cinematograph film; they could only register what was impressed on them from an outer world over which they had no control.

Theoretical physics is no longer concerned to study the Newtonian universe which it once believed to exist in its own right in space and time. It merely sets before itself the modest task of reducing to law and order the impressions that the universe makes on our senses. It is not concerned with what lies beyond the gateways of knowledge, but with what enters through the gateways of knowledge. It is concerned with appearances rather than reality, so that its task resembles that of the cartographer or map-maker rather than that of the geologist or mining engineer.

Now the cartographer knows that a map may be drawn in many ways, or, as he would himself say, many kinds of projection are available. Each one has its merits, but it is impossible to find all the merits we might reasonably desire combined in one single map. It is reasonable to demand that each bit of territory should look its proper shape on the map; also that each should look its proper rela-

tive size. Yet even these very reasonable requirements can not usually be satisfied in a single map; the only exception is when the map is to contain only a small part of the whole surface of the globe. In this case, and this only, all the qualities we want can be combined in a single map, so that we simply ask for a map of the county of Surrey without specifying whether it is to be a Mercator's or orthographic or conic projection, or what not.

All this has its exact counterpart in the map-making task of the physicist. The Newtonian mechanics was like the map of Surrey, because it dealt only with a small fraction of the universe. It was concerned with the motions and changes of medium-sized objects —objects comparable in size with the human body—and for these it was able to provide a perfect map which combined in one picture all the qualities we could reasonably demand. But the inconceivably great and the inconceivably small were equally beyond its ken. As soon as science pushed out—to the cosmos as a whole in one direction and to sub-atomic phenomena in the other—the deficiencies of the Newtonian mechanics became manifest. And no modification of the Newtonian map was able to provide the two qualities which this map had itself encouraged us to expect—a materialism which exhibited the universe as constructed of matter lying within the framework of space and time, and a determinism which provided an answer to the question "What is going to happen next?"

When geography can not combine all the qualities we want in a single map, it provides us with more than one map. Theoretical physics has done the same, providing us with two maps which are commonly known as the particle-picture and the wave-picture.

The particle-picture is a materialistic picture which caters for those who wish to see their universe mapped out as matter existing in space and time. The wave-picture is a determinist picture which caters for those who ask the question "What is going to happen next?" It is perhaps better to speak of these two pictures as the particle-parable and the wave-parable. For this is what they really are, and the nomenclature warns us in advance not to be surprised at inconsistencies and contradictions.

Let me remind you, as briefly as possible, how this pair of pictures or parables have come to be in existence side by side.

The particle-parable, which was first in the field, told us that the material universe consists of particles existing in space and time. It was created by the labours of chemists and experimental physicists, working on the basis provided by the classical physics. Its time of testing came in 1913, when Bohr tried to find out whether the two particles of the hydrogen atom could possibly produce the highly complicated spectrum of hydrogen by their motion. He found a type of motion which could produce this spectrum down to its minutest details, but the motion was quite inconsistent with the mechanistic determinism of the Newtonian mechanics. The electron did not move continuously through space and time, but jumped, and its jumps were not governed by the laws of mechanics, but to all appearance, as Einstein showed more fully four years later, by the laws of probability. Of 1,000 identical atoms, 100 might make the jump, while the other 900 would not. Before the jumps occurred, there was nothing to show which atoms were going to jump. Thus the particle-picture conspicuously failed to provide an answer to the question, "What will happen next?"

Bohr's concepts were revolutionary, but it was soon found they were not revolutionary enough, for they failed to explain more complicated spectra, as well as certain other phenomena.

Then Heisenberg showed that the hydrogen spectrum—and, as we now believe, all other spectra as well—could be explained by the motion of something which was rather like an electron, but did not move in space and time. Its position was not specified by the usual coordinates x, y, z of coordinate geometry, but by the mathematical abstraction known as a matrix. His ideas were rather too abstract even for mathematicians, the majority of whom had quite forgotten what matrices were. It seemed likely that Heisenberg had unravelled the secret of the structure of matter, and yet his solution was so far removed from the concepts of ordinary life that another parable had to be invented to make it comprehensible.

The wave-parable serves this purpose; it does not describe the universe as a collection of particles but as a system of waves. "The universe is no longer a deluge of shot from a battery of machine-guns, but a stormy sea with the sea taken away and only the abstract quality of storminess left—or the grin of the Cheshire cat if we can

think of a grin as undulatory." This parable was not devised by Heisenberg, but by de Broglie and Schrödinger. At first they thought their waves merely provided a superior model of an ordinary electron; later it was established that they were a sort of parable to explain Heisenberg's pseudo-electron.

Now the pseudo-electron of Heisenberg did not claim to account for the spectrum emitted by a single atom of gas, which is something entirely beyond our knowledge or experience, but only that emitted by a whole assembly of similar atoms; it was not a picture of one electron in one atom, but of all the electrons in all the atoms.

In the same way the waves of the wave-parable do not picture individual electrons, but a community of electrons—a crowd—as, for instance, the electrons whose motion constitutes a current of electricity.

In this particular instance the waves can be represented as travelling through ordinary space. Except for travelling at a different speed, they are very like the waves by which Maxwell described the flow of radiation through space, so that matter and radiation are much more like one another in the new physics than they were in the old.

In other cases, ordinary time and space do not provide an adequate canvas for the wave-picture. The wave-picture of two currents of electricity, or even of two electrons moving independently, needs a larger canvas—six dimensions of space and one of time. There can be no logical justification for identifying any particular three of these six dimensions with ordinary space, so that we must regard the wave-picture as lying entirely outside space. The whole picture, and the manifold dimensions of space in which it is drawn, become pure mental constructs—diagrams and frameworks we make for ourselves to help us understand phenomena.

In this way we have the two coexistent pictures—the particle-picture for the materialist and the wave-picture for the determinist. When the cartographer has to make two distinct maps to exhibit the geography of, say, North America, he is able to explain why two maps are necessary, and can also tell us the relation between the two—he can show us how to transform one into the other. He will tell us, for instance, that he needs two maps simply because he is

restricted to flat surfaces—pieces of paper. Give him a sphere instead, and he can show us North America, perfectly and completely, on a single map.

The physicist has not yet found anything corresponding to this sphere; when, if ever he does, the particle-picture and the wave-picture will be merged into a single new picture. At present some kink in our minds, or perhaps merely some ingrained habit of thought, prevents our understanding the universe as a consistent whole—just as the ingrained habits of thought of a "flat-earther" prevents his understanding North America as a consistent whole. Yet, although physics has so far failed to explain why two pictures are necessary, it is, nevertheless, able to explain the relation between the particle-picture and the wave-picture in perfectly comprehensible terms.

The central feature of the particle-picture is the atomicity which is found in the structure of matter. But this atomicity is only one expression of a fundamental coarse-grainedness which pervades the whole of nature. It crops up again in the fact that energy can only be transferred by whole quanta. Because of this, the tools with which we study nature are themselves coarse-grained; we have only blunt probes at our disposal, and so can never acquire perfectly precise knowledge of nature. Just as, in astronomy, the grain of our photographic plates prevents our ever fixing the position of a star with absolute precision, so in physics we can never say that an electron is here, at this precise spot, and is moving at just such and such a speed. The best we can do with our blunt probes is to represent the position of the electron by a smear, and its motion by a moving smear which will get more and more blurred as time progresses. Unless we check the growth of our smear by taking new observations, it will end by spreading through the whole of space.

Now the waves on an electron or other piece of matter are simply a picture of just such a smear. Where the waves are intense, the smear is black, and conversely. The nature of the smear —whether it consists of printer's ink, or, as was at one time thought, of electricity—is of no importance; this is mere pictorial detail. All that is essential is the relative blackness of the smear at different

places—a ratio of numbers which measures the relative chance of electrons being at different points of space.

The relation between the wave-picture and the particle-picture may be summed up thus: the more stormy the waves at any point in the wave-picture, the more likely we are to find a particle at that point in the particle-picture. Yet, if the particles really existed as points, and the waves depicted the chances of their existing at different points of space—as Maxwell's law does for the molecules of a gas—then the gas would emit a continuous spectrum instead of the line-spectrum that is actually observed. Thus we had better put our statement in the form that the electron is not a point-particle, but that if we insist on picturing it as such, then the waves indicate the relative proprieties of picturing it as existing at the different points of space. But propriety relative to what?

The answer is—relative to our own knowledge. If we know nothing about an electron except that it exists, all places are equally likely for it, so that its waves are uniformly spread through the whole of space. By experiment after experiment we can restrict the extent of its waves, but we can never reduce them to a point, or indeed below a certain minimum; the coarse-grainedness of our probes prevents that. There is always a finite region of waves left. And the waves which are left depict our knowledge precisely and exactly; we may say that they are waves of knowledge—or, perhaps even better still, waves of imperfections of knowledge—of the position of the electron.

And now we come to the central and most surprising fact of the whole situation. I agree that it is still too early, and the situation is still too obscure, for us fully to assess its importance, but, as I see it, it seems likely to lead to radical changes in our views not only of the universe but even more of ourselves. Let us remember that we are dealing with a system of waves which depict in a graphic form our knowledge of the constituents of the universe. The central fact is this: the wave-parable does not tell us that these waves depict our knowledge of nature, but that they are nature itself.

If we ask the new physics to specify an electron for us, it does not give us a mathematical specification of an objective electron, but rather retorts with the question, "How much do you know about

the electron in question?" We state all we know, and then comes the surprising reply, "That is the electron." The electron exists only in our minds—what exists beyond, and where, to put the idea of an electron into our minds we do not know. The new physics can provide us with wave-pictures depicting electrons about which we have varying amounts of knowledge, ranging from nothing at all to the maximum we can know with the blunt probes at our command, but the elctron which exists apart from our study of it is quite beyond its purview.

Let me try and put this in another way. The old physics imagined it was studying an objective nature which had its own existence independently of the mind which perceived it—which, indeed, had existed from all eternity, whether it was perceived or not. It would have gone on imagining this to this day, had the electron observed by the physicists behaved as on this supposition it ought to have done.

But it did not so behave, and this led to the birth of the new physics, with its general thesis that the nature we study does not consist so much of something we perceive as of our perceptions; it is not the object of the subject-object relation, but the relation itself. There is, in fact, no clear-cut division between the subject and object; they form an indivisible whole which now becomes nature. This thesis finds its final expression in the wave-parable, which tells us that nature consists of waves and that these are of the general quality of waves of knowledge, or of absence of knowledge, in our own minds.

Let me digress to remind you that if ever we are to know the true nature of waves, these waves must consist of something we already have in our own minds. Now knowledge and absence of knowledge satisfy this criterion as few other things could; waves in an ether, for instance, emphatically did not. It may seem strange, and almost too good to be true, that nature should in the last resort consist of something we can really understand; but there is always the simple solution available that the external world is essentially of the same nature as mental ideas.

At best this may seem very academic and up in the air—at the worst it may seem stupid and even obvious. I agree that it would

be so, were it not for the one outstanding fact that observation supports the wave-picture of the new physics whole-heartedly and without hesitation. Whenever the particle-picture and the wave-picture have come into conflict; observation has discredited the particle-picture and supported the wave-picture—not merely, be it noted, as a picture of our knowledge of nature, but as a picture of nature itself. The particle-parable is useful as a concession to the materialistic habits of thought which have become ingrained in our minds, but it can no longer claim to fit the facts, and, so far as we can at present see, the truth about nature must lie very near to the wave-parable.

Let me digress again to remind you of two simple instances of such conflicts and of the verdicts which observation has pronounced upon them.

A shower of parallel-moving electrons forms in effect an electric current. Let us shoot with a shower of electrons at a thin film of metal, as Professor G. P. Thomson did. The particle-parable compares it to a shower of hailstones falling on a crowd of umbrellas; we expect the elctrons to get through somehow or anyhow and come out on the other side as a disordered mob. But the wave-parable tells us that the shower of electrons is a train of waves. It must retain its wave-formation, not only in passing through the film, but also when it emerges on the other side. And this is what actually happens: it comes out and forms a wave-pattern which can be predicted—completely and perfectly—from its wave-picture before it entered the film.

Next let us shoot our shower of electrons against the barrier formed by an adverse electromotive force. If the electrons of the shower have a uniform energy of ten volts each, let us throw them against an adverse potential difference of a million volts. According to the particle-parable, it is like throwing a handful of shot up into the air; they will all fall back to earth in time—the conservation of energy will see to that. But the wave-parable again sees our shower of electrons as a train of waves—like a beam of light—and sees the potential barrier as an obstructing layer—like a dirty window pane. The wave-parable tells us that this will check, but not entirely stop, our beam of electrons. It even shows us how to cal-

culate what fraction will get through. And just this fraction, in actual fact, does get through; a certain number of ten-volt electrons surmount the potential barrier of a million volts—as though a few of the shot thrown lightly up from our hands were to surmount the earth's gravitational field and wander off into space. The phenomenon appears to be in flat contradiction to the law of conservation of energy, but we must remember that waves of knowledge are not likely to own allegiance to this law.

A further problem arises out of this experiment. Of the millions of electrons of the original shower, which particular electrons will get through the obstacle? Is it those who get off the mark first or those with the highest turn of speed or what? What little extra have they that the others haven't got?

It seems to be nothing more than pure good luck. We know of no way of increasing the chances of individual electrons; each just takes its turn with the rest. It is a concept with which science has been familiar ever since Rutherford and Soddy gave us the law of spontaneous disintegration of radioactive substances—of a million atoms ten broke up every year, and no help we could give to a selected ten would cause fate to select them rather than the ten of her own choosing. It was the same with Bohr's model of the atom; Einstein found that without the caprices of fate it was impossible to explain the ordinary spectrum of a hot body; call on fate, and we at once obtained Planck's formula, which agrees exactly with observation.

From the dawn of human history, man has been wont to attribute the results of his own incompetence to the interference of a malign fate. The particle-picture seems to make fate even more powerful and more all-pervading than ever before; she not only has her finger in human affairs, but also in every atom in the universe. The new physics has got rid of mechanistic determinism, but only at the price of getting rid of the uniformity of nature as well!

I do not suppose that any serious scientist feels that such a statement must be accepted as final; certainly I do not. I think the analogy of the beam of light falling on the dirty window-pane will show us the fallacy of it.

Heisenberg's mathematical equation shows that the energy of a

beam of light must always be an integral number of quanta. We have observational evidence of this in the photoelectric effect, in which atoms always suffer damage by whole quanta.

Now this is often stated in parable form. The parable tells us that light consists of discrete light-particles, called photons, each carrying a single quantum of energy. A beam of light becomes a shower of photons moving through space like the bullets from a machine-gun; it is easy to see why they necessarily do damage by whole quanta.

When a shower of photons falls on a dirty window-pane, some of the photons are captured by the dirt, while the rest escape capture and get through. And again the question arises: How are the lucky photons singled out? The obvious superficial answer is a wave of the hand towards fortune's wheel; it is the same answer that Newton gave when he spoke of his "corpuscles of light" experiencing alternating fits of transmission and reflection. But we readily see that such an answer is superficial.

Our balance at the bank always consists of an integral number of pence, but it does not follow that it is a pile of bronze pennies. A child may, however, picture it as so being, and ask his father what determines which particular pennies go to pay the rent. The father may answer "Mere chance"—a foolish answer, but no more foolish than the question. Our question as to what determines which photons get through is, I think, of a similar kind, and if nature seems to answer "Mere chance," she is merely answering us according to our folly. A parable which replaces radiation by identifiable photons can find nothing but the finger of fate to separate the sheep from the goats. But the finger of fate, like the photons themselves, is mere pictorial detail. As soon as we abandon our picture of radiation as a shower of photons, there is no chance but complete determinism in its flow. And the same is, I think, true when the particle-photons are replaced by particle-electrons.

We know that every electric current must transfer electricity by complete electron-units,but this does not entitle us to replace an electric current by a shower of identifiable electron-particles. Indeed the exclusion-principle of Pauli, which is in full agreement with observation, definitely forbids our doing so. When the red and

white balls collide on a billiard table, red may go to the right and white to the left. The collision of two electrons A and B is governed by similar laws of energy and momentum, so that we might expect to be able to say that A goes to the right, and B to the left or *vice versa*. Actually we must say no such thing, because we have no right to identify the two electrons which emerge from the collision with the two that went in. It is as though A and B had temporarily combined into a single drop of electric fluid, which had subsequently broken up into two new electrons, C, D. We can only say that after the collision C will go to the right, and D to the left. If we are asked which way A will go, the true answer is that by then A will no longer exist. The superficial answer is that it is a pure toss-up. But the toss-up is not in nature, but in our own minds; it is an even chance whether we choose to identify C with A or with B.

Thus the indeterminism of the particle-picture seems to reside in our own minds rather than in nature. In any case this picture is imperfect, since it fails to represent the facts of observation. The wave-picture, which observation confirms in every known experiment, exhibits a complete determinism.

Again we may begin to feel that the new physics is little better than the old—that it has merely replaced one determinism by another. It has; but there is all the difference in the world between the two determinisms. For in the old physics the perceiving mind was a spectator; in the new it is an actor. Nature no longer forms a closed system detached from the perceiving mind; the perceiver and perceived are interacting parts of a single system. The nature depicted by the wave-picture in some way embraces our minds as well as inanimate matter. Things still change solely as they are compelled, but it no longer seems impossible that part of the compulsion may originate in our own minds.

Even the inadequate particle-picture told us something very similar in its own roundabout stammering way. At first it seemed to be telling us of a nature distinct from our minds, which moved as directed by throws of the dice, and then it transpired that the dice were thrown by our own minds. Our minds enter into both pictures, although in somewhat different capacities. In the particle-picture the mind merely decides under what conventions the map is to be

drawn; in the wave-picture it perceives and observes and draws the map. We should notice, however, that the mind enters both pictures only in its capacity as a receptacle—never as an emitter.

The determinism which appears in the new physics is one of waves, and so, in the last resort, of knowledge. Where we are not ourselves concerned, we can say that event follows event; where we are concerned, only that knowledge follows knowledge. And even this knowledge is one only of probabilities and not of certainties; it is at best a smeared picture of the clear-cut reality which we believe to lie beneath. And just because of this, it is impossible to decide whether the determinism of the wave-picture originates in the underlying reality or not—can our minds change what is happening in reality, or can they only make it look different to us by changing our angle of vision? We do not know, and as I do not see how we can ever find out. My own opinion is that the problem of free will will continue to provide material for fruitless discussion until the end of eternity.

The contribution of the new physics to this problem is not that it has given a decision on a long-debated question, but that it has reopened a door which the old physics had seemed to slam and bolt. We have an intuitive belief that we can choose our lunch from the menu or abstain from housebreaking or murder; and that by our own volition we can develop our freedom to choose. We may, of course, be wrong. The old physics seemed to tell us that we were, and that our imagined freedom was all an illusion; the new physics tells us it may not be.

The old physics showed us a universe which looked more like a prison than a dwelling-place. The new physics shows us a building which is certainly more spacious, although its interior doors may be either open or locked—we can not say. But we begin to suspect it may give us room for such freedom as we have always believed we posseessed; it seems possible at least that in it we can mould events to our desire, and live lives of emotion, intellect and endeavour. It looks as though it might form a suitable dwelling-place for man, and not a mere shelter for brutes.

The new physics obviously carries many philosophical implications, but these are not easy to describe in words. They can not be

summed up in the crisp, snappy sentences beloved of scientific journalism, such as that materialism is dead or that matter is no more. The situation is rather that both materialism and matter need to be redefined in the light of our new knowledge. When this has been done, the materialist must decide for himself whether the only kind of materialism which science now permits can be suitably labelled materialism, and whether what remains of matter should be labelled as matter or as something else; it is mainly a question of terminology.

What remains is in any case very different from the full-blooded matter and the forbidding materialism of the Victorian scientist. His objective and material universe is proved to consist of little more than constructs of our own minds. To this extent, then, modern physics has moved in the direction of philosophic idealism. Mind and matter, if not proved to be of similar nature, are at least found to be ingredients of one single system. There is no longer room for the kind of dualism which has haunted philosophy since the days of Descartes.

This brings us at once face to face with the fundamental difficulty which confronts every form of philosophical idealism. If the nature we study consists so largely of our own mental constructs, why do our many minds all construct one and the same nature? Why, in brief, do we all see the same sun, moon and stars?

I would suggest that physics itself may provide a possible although very conjectural clue. The old particle-picture which lay within the limits of space and time broke matter up into a crowd of distinct particles, and radiation into a shower of distinct photons. The newer and more accurate wave-picture, which transcends the frame-work of space and time, recombines the photons into a single beam of light and the shower of parallel-moving electrons into a continuous electric current. Atomicity and division into individual existences are fundamental in the restricted space-time picture, but disappear in the wider, and as far as we know more truthful, picture which transcends space and time. In this, atomicity is replaced by what General Smuts would describe as "holism"—the photons are no longer distinct individuals each going its own way, but members of a single organization or whole—a beam of light. The same is

true, *mutatis mutandis*, of the electrons of a parallel-moving shower. The biologists are beginning to tell us, although not very unanimously, that the same may be true of the cells of our bodies. And is it not conceivable that what is true of the objects perceived may be true also of the perceiving minds? When we view ourselves in space and time we are quite obviously distinct individuals; when we pass beyond space and time we may perhaps form ingredients of a continuous stream of life. It is only a step from this to a solution of the problem which would have commended itself to many philosophers, from Plato to Berkeley, and is, I think, directly in line with the new world-picture of modern physics.

REVIEW OF PUBLICATIONS

The Calculation of the Orbits of Asteroids and Comets, by Kenneth P. Williams, Professor of Mathematics, Indiana University. 211 pages, 6¾ x 10 in. Bloomington, Indiana: The Principia Press, 1934. Price $3.25.

The calculation of an orbit for a planet or a comet is a lengthy affair, one usually not suited to undergraduate study. Not many years ago, the student beginning this work studied as his texts the classic works of Oppolzer, Bauschinger or Klinkerfues. These works still remain standards but are somewhat bewildering to the beginner by the array of formulae they present to meet various exigencies which may arise. Two texts have been published recently, one by Stracke in German and the other by Crawford in English, which aim to present the same material in shorter form, in a form more suited to the beginner. The present work still further abbreviates the problem, and we believe that for the first time we have a text which can be covered in an undergraduate course of study in one year.

Chapter I presents the subject matter of astronomical co-ordinates in a way which emphasizes the various corrections forced on the astronomer to make them of service in mathematical analysis. This is a condensed but a particularly good chapter. In Chapter II such interpolation formulae as are necessary to the work are collated with examples. Chapter III solves the two-body problem and includes expressions for the areas of the triangle formed by two positions of the body and the sun. Various formulae for the position of the body in the orbit are developed in Chapter IV. Chapter V begins the work proper on the problem of the determination of the orbit. In this chapter the possibility of a direct solution in terms of the elements is discussed and the reasons given why it is better to make the solution in terms of other unknowns given in Chapter VI. The methods of Laplace, Gauss and others are then treated in Chapters VII, VIII and IX, and the methods of computing the ephemeris in Chapter X.

It would hardly be possible to include less in the subject matter of a course and make it intelligible, although it is quite likely that practical examples of computing an orbit by all three methods could not be worked out by a single student in one year.

The printing and binding of the book are excellent. It appears to the reviewer to be the best text which has yet appeared as a first course in orbit computation.

R. K. Y.

When the Stars Come Out, by Robert H. Baker. 188 pages, 5½ x 8 in., with 32 pages of plates. N.Y., Viking Press; distributed in Canada by the Macmillan Co. of Canada, 1934.

This is another popular book on astronomy, intended for young people of the high school and college age. The text, as we should expect, is written in a clear, flowing style and the subjects of the fourteen chapters are well chosen. The first four chapters deal with the sky; then follow the moon, the sun, meteors (exceptionally well done) and the other celestial bodies. There is a certain continuity in the chapters but yet they are so separate that any one of them may be read at any time with understanding and pleasure.

The special feature of the book is that the title page and the illustrations are printed in blue, to represent the blue sky. The pictures of the sky at different seasons and the day and night views of the Adler Planetarium are perhaps improved by being thus tinted; and the others may also give added attraction to the young, but they seem peculiar to the old astronomer.

The present writer hopes that many persons will use this volume for a Christmas gift: nothing better than a book about the heavens!

C. A. C.

Histoire de l'astronomie stellaire jusqu'a l'epoque contemporaine, by H. Mineur. 57 pages, price 15 fr.

Éléments de statistique mathématique applicable a l'étude de l'astronomie stellaire, by H. Mineur. 40 pages, 12 fr.

Photographie stellaire. Mesure photographique des positions et des magnitudes des étoiles, by H. Mineur. 67 pages, price 18 fr.

Le calcul symbolique, by Pierre Humbert. 31 pages, price 10 fr.

Travaux récents sur les molécules dans le soleil, les planètes et les étoiles, by P. Swings. 45 pages, price 14 fr.

The above are five pamphlets in the series of *Actualités scientifique et industrielles* prepared by competent scientific men and published by Hermann in Paris. The first three deal with stellar astronomy. The treatment is, of course, brief, but the subject is clearly outlined and the methods used are explained fully enough to enable one to obtain a good view of the present condition of the branch of science involved.

In the first of the above list the history of stellar astronomy is sketched. In it there are 13 figures and two plates, the latter of which contain portraits of Kapteyn and Shapley. There are sketch-maps of the different continents on which are shown the location of the chief observatories. The Dominion Astrophysical Observatory at Victoria is placed about where Edmonton is. Our brethren from Europe are always accorded a warm welcome when they visit Canada, and a trip to the western coast gives an idea of the geography of our country and its great distances as can be obtained in no other way. The gifted author of the three pamphlets on stellar astronomy should come to see us. There were also noted a few errors in proof-reading, but all these errors are slight and do not alter the value of the treatment.

The whole series deserves high commendation. In no better way could one obtain a good knowledge of the present state of physical science. The pamphlets published in 1934 began with No. 79 and the last one in the above list is No. 162. Apparently they are meeting a real need.

C. A. C.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

The Moon giving Trouble Again

A good friend sends the following:

Lloyd C. Douglas, author of "Magnificent Obsession", during a delightfully humorous lecture on the trials of authorship complained of the practice of astronomers who, after a book was published, were sure to call attention to the fact that during a romantic scene the moon had been put in the wrong place. Surely Mr. Douglas would not deprive the astronomer of a certain relaxation he feels in setting an author right. Also, it might be well for authors to acquire the virtue of being accurate. When an author ventures to refer to a matter in the field of science he should know what he is talking about, otherwise the reader develops a feeling that the author is liable to err in other matters as well.

In "The Extraordinary Adventure of a First Mate", by W. Clark Russell (Dodd, Mead & Co., "Omnibus of Adventure"), occurs the following:

> *March 23rd.* 2° 12′ N.Lat., 33° 27′ W.long., .. "When the dusk came along the silence upon the sea was something to put all sorts of moods into a man. The sky was a hovering velvet stretch of stars, with a young moon lying curled among them.... Half an hour later the dark curl of a light air of wind shattered the starlight in the sea.... At eleven o'clock the light breeze was still holding and the ship was floating softly through the dusk, the paring of moon swaying like a silver sickle over the port mizzen topsail yardarm."

The strange adventure of the first mate was to fall overboard and be saved by coming to rest on an island which rose by volcanic action from the bottom of the sea. But his real adventure was to see a young moon still 'swaying like a silver sickle' at least three hours after sunset. Perhaps it was this strange behaviour of the moon which caused the volcanic upheaval!

Halley, his Comet and his Mortality Tables

Few people are aware that Edmund Halley has any claim to fame except for his comet. From his investigation into the orbits of comets which had been observed, Halley predicted that a comet

which had appeared in 1682 would return in 1758 or 1759 and each 75 or 76 years thereafter; and further, that other comets might return also. But another side of his activity was discussed recently at a convention of underwriters at Milwaukee by Mr. John Nelson, who for twenty years was a prominent newspaper journalist in Victoria and Vancouver, B.C., and is now Director of Public Relations of the Sun Life Assurance Co., Montreal, as well as being President of International Rotary. Would that all such publicity men were equally well informed in astronomical matters! The following extracts are taken from his address:

Early one May morning almost a quarter of a century ago, some of you rose before daylight and, peering out into the darkness, saw a comet with a long tail of swirling star-dust sweeping across the sky. That comet had not been seen for nearly a century. But you knew it would be there at the precise point at that exact hour, and you set your alarm clocks accordingly, because more than two hundred years before a clever mathematician and astronomer, Edmund Halley, had worked it all out. He had trailed this celestial vagabond half way round the world and had calculated its orbit and its movements so accurately that he knew just what it would do and where it would be at a given time. For the first time in human history he was able to announce when it would return to view. He set the dates for 1758, 1835 and 1910. And he was right. So they made him Astronomer Royal and attached his name to his discovery. It was thence-forward Halley's Comet.

This vagrant visitor had terrified people for over two thousand years. It appeared and disappeared without warning. The ancients attributed to it all sorts of malign influences. Hence its appearance caused profound apprehension and alarm, for it was the supposed precursor and the portent of all sorts of human ills—war, famine, plague and death.

Seneca, the Roman philosopher, was sure that there was no ground for these fears. He wasn't able to explain it himself. Like a good many other philosophers, he perhaps hadn't much facility in figures. But he staked his reputation on the statement that "some day there will rise a man who will demonstrate in what regions of the heavens the comets take their way, why they journey so far apart from the other planets, what their size, what their nature." Seneca, too, proved to be right.

Probably Halley had read what Seneca said. Perhaps it helped to fire his scientific zeal. Whether this was the case or not, his discoveries lifted a great terror from the minds of men. He delivered his own—and all subsequent generations—from an age-old fear. They now knew when and where to expect these celestial visitors. Halley showed that comets worked under fixed laws that could be determined. If they were not under human control, they were, at least, within the range of human knowledge. The inhabitants of this world had pierced

the secrets of another and a very distant world. And when other worlds cease to mystify and surprise, they lose their capacity to terrify.

It was natural that an achievement so wonderful—one that liberated human minds—should have brought fame to the discoverer, and that his name should be forever linked with the orb whose vagrant journeys he was able so accurately to chart.

Halley had his head in the clouds, but he kept his feet on the ground. His interest in matters celestial was no greater than in things terrestrial. And his conclusions in one case were as final and as authentic as in the other. He was not content with charting the progress of the stars in the heavens; he applied the same meticulous study to the course of human life on earth. He had seen the first rude attempts of men collectively to provide for their families after their deaths, and had noted how every such effort was rendered futile, because of the lack of data as definite regarding human life as he had found necessary in determining the course of the comet.

So he set out to supply that need. He produced a comprehensive mortality table. He made sure that these figures made him as certain of what was happening on earth as he was of what was going on in the heavens. So he established a system that not only delivered many from the fantastic fear of occasional visitations, but the whole human family of one of the chief terrors of death.

His discoveries in mathematical science were more practical then and ultimately affected the lives of millions uninterested in and unaffected by his discoveries in the heavens. There were not at that time available in England vital statistics sufficiently complete for actuarial purposes. But over in Breslau in Silesia, the authorities had begun to record the births and deaths, together with particulars as to age and sex. Halley tabulated these. There had been an attempt earlier to make the same analysis from the mortuary returns of London but it lacked all the detail essential for the purpose. Halley's Breslau Table was the earliest available that was drawn from actual experience. By 1693 Halley had completed his paper and submitted it to the government.

Halley's tables, while they had a permanent value as the foundation for actuarial science, proved to have an immediate and outstanding value owing to the troubled condition of the time.

The Disc of Glass for the 200-inch Telescope

From *Science Service* comes information regarding the disc of glass for the mirror of the 200-inch telescope of the California Institute of Technology. As is well known, on March 25 last a disc was poured. Projecting from the bottom of the mould were cores or "pylons" which were to give to the disc a honeycombed back, the upper portion or face, of course, being solid. During the pouring operation three of these pylons broke off and floated to the surface. They were raked off and the pouring completed. It was thought

probable that the disc would still be quite usable, but the Corning Glass Works did not wish any doubt to exist as to the nature of the disc they were to supply for this historic instrument, and gave orders to construct a new mould and pour another disc. The first disc has now been removed from the annealing oven and appears of good quality. On account of the accident during the pouring, holes will have to be drilled or ground into the lower face of the disc where the pylons broke away if this disc is used. The pouring of the second disc is to take place before the end of the year. It will be solid, not honeycombed on the back, and the task of pouring it will on that account be simpler. When it is ready there will be a choice between the two discs. Great credit is due to the Corning Glass Works for their wonderful success in producing these immense blocks of glass; and when we remember that the material used has a melting point almost as high as that of iron, the greatness of the achievement is much heightened.

Death of Professor Sir Edgeworth David

Sir Edgeworth David, the distinguished Australian geologist, died at Sydney, N.S.W., on August 28, at the age of 76. A note in *Science* of October 19, from a correspondent says:

> "His death will be a great blow to many of his friends in this country and throughout the world. Professor David was the Antarctic explorer who led the expedition to the South Magnetic Pole; he was in charge of the successful Funafuti boring of the Royal Society to determine the origin of atolls; the teacher of almost every Australian geologist worthy of the name; and altogether one of the finest men that ever lived."

What better tribute could be paid to any person? Professor David had just completed his masterpiece, "The Geology of Australia." Wounds received during the war, where he was chief geologist of the Australian Corps, had brought ill health and had caused him much suffering of late.

The members of the Canadian expedition to Australia to observe the eclipse of the sun on September 21, 1922, received much kind attention from Sir Edgeworth David and his family. At

Sydney University he gave them a "lecturette", as he called it, in which he explained the nature of the country on the northwest coast where the eclipse was to be observed, and he answered in a very entertaining way the many questions asked him. The present writer will never forget his association with Sir Edgeworth, who is remembered as a charming, modest and able man.

WANTED: DIE ASTRONOMISCHE NACHRICHTEN

The Editor of this JOURNAL wishes to secure the *Astronomische Nachrichten* from volume 210 to the present time. Address, University of Toronto, Toronto, Canada.

C. A. C.

METEOR NEWS

Observations relating to meteors and meteorites are cordially invited.

The Leonids, 1934

After the experience of meteor observers during the last few years it is dangerous to make any kind of prediction concerning the Leonid meteors. All we can say is that this year's apparition should certainly be watched most carefully. No one can say that a good showing is impossible since the best display of the previous return occurred in 1901. It is to be hoped that the Leonids repeat that performance. Observations will be made at the David Dunlap Observatory on Nov. 14-15, 15-16, 16-17, and possibly on Nov. 17-18. The writer will be glad to mail maps and instructions to any who may wish to organize observation groups at other points.

Observations of the 1934 Perseids

A visual and photographic campaign for the observation of the Perseid meteors was organized in Canada this past summer and, despite unfavourable weather conditions at many points, a large number of excellent observations were made. The preliminary results of the visual program will be reported this month while the results of the photographic program will be discussed in the next number of the JOURNAL.

The general program was planned in the same way as previous coöperative observations reported in these pages. Emphasis was laid on plotting and timing accurately all meteors recorded and on complete observation of all persistent trains. The observers contributing to this program include the majority of those who observed the Leonids last fall, as well as members from the Montreal, Ottawa, Toronto, Hamilton and Winnipeg centers of the Society. An excellent set of records was sent in from the Montreal Boy Scouts who observed under Mr. E. Russell Paterson at Camp Tamaracouta. A total of 6280 observations was received from 45 organized groups, the majority of these being located in Ontario. The personnel of these groups, totalling 132, is listed below, together with the locality where the observations were made. The province is added only when it is not Ontario.

PERSEID OBSERVATION GROUPS, 1934

1. *Scarcliff*—A. D. Misener, Miss M. Dodge, W. B. Gibson (A.M.S.)
2. *Lake Simcoe*—Miss E. M. Rutledge, Miss H. Fuiniss.
3. *Toronto*—Mrs. B. Richards.
4. *Stanley Brae*—W. M. Gray, W. C. Weaver, J. S. Reid.
5. *Norway Bay, Que.*—Miss M. F. James, Miss L. E. Pallett.
6. *Moon River*—P. D. Jose, Miss P. Weston, K. Jones.
7. *Dom. Obs'y., Ottawa*—M. M. Thomson, Miss M. S. Burland, W. B. Knowles.
8. *Richmond Hill*—J. S. Waddell, R. J. Waddell.
9. *Calgary, Alta.*—Finlay Moore.
10. *Scrabble Hill, N.Y.*—Mrs. E. E. Blaauw, E. Raab, Miss M. Geyer.
11. *Wingham*—M. M. Foran, C. E. Thomson.
12. *Silver Islet*—T. R. Jones, J. R. Jones, E. T. Mills.

12a *Macdiarmid*—G. V. Jones, J. A. Campbell.

13. *Norway Bay, Que.*—F. W. Matley.
14. *Gull Lake*—Miss L. H. Newton, Mrs. H. K. Newton, Miss B. Newton, Miss M. Huddart, Miss B. Niemeier, J. M. Huddart.
15. *Huttonville*—Philip Perry.
16. *Kincardine*—D. A. MacRae, A. H. Armstrong, E. McKay, J. C. Davidson, E. H. Roden.
17. *Brownsville*—E. H. Barnhardt.
18. *Algonquin Park*—Miss Y. Gignac, Miss L. Smith, Miss G. M. Millar, Miss M. Millar, Miss N. Millen.
19. *Gull Lake*—J. T. King, Miss D. King.
20. *Brampton*—Miss M. Quin, Miss H. Hagen.
21. *Milverton*—Miss E. L. Morley.
22. *Hagersville*—Miss E. Dougherty, M. Dougherty.
23. *Jarvis*—R. M. Miller.
24. *Hamilton*—Wm. Findlay, T. H. Wingham.
25. *Cayuga*—E. G. Campbell, R. G. Campbell.
26. *Welland*—L. Hornby.
27. *Ft. Erie*—W. H. Almendinger, J. Hanna.
28. *Montreal, Que.*—F. J. DeKinder, O. A. Ferrier, F. Morgan, J. Hall.
29. *Port Sandfield*—Mrs. R. M. Millman, Mrs. J. H. Millman, J. M. Millman, R. N. Millman, Mrs. P. M. Millman, J. H. Millman, A. D. Misener, W. B. Gibson (A.M.S.), P. M. Millman.
30. *Linwood*—R. B. Laing, J. C. Strachan.
31. *Peterboro*—W. J. Duncan, J. A. Mitchell.
32. *Thessalon*—F. A. O. Banks.
33. *Montreal, Que.*—John Forbes.
34. *Camp Tamaracouta, Que.*—E. Russell Patterson, G. Pickering, A. Goodman, H. Brownrigg, J. Marshall, H. Patterson, D. Chute, E. Neill, F. Pickering.
35. *Georgian Bay*—E. W. Bullock, B. Duggan, A. Beatty.
36. *Winnipeg, Man.*—D. R. P. Coats.

37. *Scarboro Bluffs*—Wm. C. Macready, S. Hemings, W. Phair, J. Vincent, D. Earle, E. England.
38. *Victoria Harbour*—C. E. Strachan, J. D. MacKinnon.
39. *Sturgeon Lake*—J. C. Strachan, J. Flanagan, W. M. Armstrong.
40. *Dunlap Obs'y*—

    Aug. 10-11, Miss E. M. Rutledge, Miss M. Hazelton, Miss F. Hazelton, Miss M. A. Clendening, Miss M. McKinley, Miss M. A. Eddy, D. W. R. McKinley, Miss F. S. Patterson, Miss M. J. Thomson, Miss V. E. Foster, H. E. Eby, P. M. Millman.

    Aug. 11-12, Miss F. S. Patterson, D. W. R. McKinley, Miss M. Jupp, Miss V. E. Foster, Miss M. E. Carr, Miss M. H. M. Hunt, J. M. Millman, Miss M. A. Eddy, Miss M. McKinley, Miss G. Lister, P. M. Millman.

    Aug. 12-13, Miss F. S. Patterson, H. D. Perrin, J. L. Lay, Miss V. E. Foster, Miss M. L. Gates, Miss M. A. Clendening, Miss M. A. Eddy, Miss M. H. M. Hunt, L. W. Foster, Miss M. M. Frame, Miss M. E. Carr, J. M. Millman, W. R. Harris, P. M. Millman.
41. *Windsor*—Miss R. J. Northcott, N. S. Washington.
42. *Scarboro Hts.*—S. Tooke, F. J. Maw.
43. *Toronto*—Miss F. S. Patterson.
44. *Brampton*—G. E. Hay, M. D. Stewart, G. H. Gregory, J. M. Millman, M. W. Forster.

The writer was greatly assisted in the reduction of this material by Miss R. J. Northcott and Mr. Murray D. Stewart and he would here like to express his thanks to them. Table I is a summary of all the observations, the actual number of different meteors seen by a group in each twenty-minute period being recorded in the vertical columns. The meteors have been divided into Perseids and Non-Perseids from an examination of the plots. As might be expected, this division is sometimes in doubt owing to the inaccuracy of plotting. Most groups had clear weather on the night of Aug. 10-11 but clouds were very generally encountered on the two following nights. The column headed "Observers" gives the average number of observers in each group, exclusive of recorders.

As the observations made at the Dunlap Observatory were fairly homogeneous the hourly rates for these have been plotted alone, all rates being reduced to six observers by the factors published previously in these Notes. Figure 1 includes the rates from the Dunlap Observatory and also representative plots of rates from some of the other groups. Each individual plot includes the meteors seen for the thirty minutes preceeding and

TABLE I

E.S.T.	h8		9			10			11			12			1			2			3			4		No. of	Totals	
Group No.	m30	50	10	30	50	10	30	50	10	30	50	10	30	50	10	30	50	10	30	50	10	30	50	10	30	Observers	Perseids	Non-Perseids
August 3-4																												
26			1	3																						1	4	
			1	*0*																								*1*
August 4-5																												
39																		2	1	3						2	6	
																		4	*4*	*2*								*10*
12									1	1	1	2														1	5	
									2	*2*	*4*	*2*																*10*
August 5-6																												
25						1																				1	1	
29					1	3	5	4	4																	3	17	
					1	*6*	*6*	*5*	*7*																			*25*
August 7-8																												
41					0	0	0	3	0	2	4	4	3	1	3	1										1	20	
					2	*1*	*2*	*1*	*0*	*2*	*3*	*0*	*1*	*3*	*0*													*15*
42												1	2	1	2											1	6	
												1	*0*	*1*	*0*													*2*
August 9-10																												
8										0	0	1														1	1	
										1	*0*	*0*																*1*
12					1	2	6																			1	9	
					2	*2*	*2*																					*6*
43							2																			1	2	
							1																					*1*

TABLE I (*continued*)

E.S.T.	h8 m30	50	9 00	10	30	50	10 00	10	30	50	11 00	10	30	50	12 00	10	30	50	1 00	10	30	50	2 00	10	30	50	3 00	10	30	50	4 00	10	30	No. of Observers	Totals Perseids	Totals Non-Perseids
Group No.																																					
August 10-11 40			2 *0*	19 *2*	12 *7*	19 *11*	10 *6*	10 *6*	12 *9*	19 *4*	18 *4*	14 *7*	13 *5*	13 *9*	23 *14*	18 *4*	23 *10*	34 *9*	26 *11*	24 *9*	31 *7*	27 *12*	17 *3*			7	384	*149*
1										1 *2*	3 *0*	1 *1*	3 *1*													1	8	*4*
44			4 *1*	5 *0*	5 *1*	11 *3*	0 *1*	4 *5*	2 *3*	1 *2*	5 *0*	6 *7*	5 *1*	8 *4*	8 *5*	15 *5*	6 *2*	19 *5*	6 *6*	12 *6*	11 *8*	4 *7*	7 *2*			3	144	*74*
34									8 *6*	19 *7*	15 *15*	16 *6*	18 *12*	15 *8*	9 *12*	16 *9*	7 *2*									6	123	*77*
12				2 *0*	2 *0*	3 *2*	8 *3*	12 *3*	13 *6*	13 *1*	21 *2*	1 *0*	15 *10*	11 *7*	12 *4*	21 *3*	18 *1*	15 *6*	20 *4*	16 *3*	17 *10*	12 *14*	17 *3*			2	249	*82*
29						3 *0*	1 *2*	4 *0*	4 *1*	3 *2*	2 *3*	8 *2*	6 *4*	7 *2*	7 *1*	3 *4*	0 *1*									2	48	*22*
31						0 *0*	1 *1*	2 *1*	0 *1*	4 *2*																1	7	*5*
35													4 *0*	1 *5*	4 *4*	3 *2*	2 *1*	3 *2*	6 *4*	3 *1*	6 *1*	8 *1*				1	40	*21*
8								5 *3*	6 *1*	1 *1*																1	12	*5*
10			4 *1*	6 *1*	4 *1*	4 *1*	3 *0*	3 *1*	2 *1*	2 *1*	1 *1*	3 *1*															2	32	*9*
14						6 *5*	2 *1*	3 *2*	3 *1*	7 *0*	2 *1*	1 *0*		12 *2*	8 *0*												2	44	*12*

TABLE I (*continued*)

EST.	h8 m30	50	9 10	30	50	10 10	30	50	11 10	30	50	12 10	30	50	1 10	30	50	3 10	30	50	3 10	30	50	4 10	30	No. of	Totals	
Group No.																										Observers	Perseids	Non-Perseids
August 10-11																												
15							1	1	2																	1	4	
							1	*2*	*0*																			*3*
16							1	1	5	2	1	2	1		5	4	4	1	1							2	28	
							1	*4*	*0*	*0*	*1*	*1*	*0*		*0*	*3*	*3*	*1*	*0*									*14*
19								1	2	3	1	1														1	8	
								0	*0*	*1*	*1*	*1*																*3*
23	1			2	1	1																				1	5	
	0			*1*	*1*	*0*																						*2*
27			0	0		0																				1	0	
			1	*1*		*1*																						*3*
28					2	1	1	0	0	1																1	5	
					1	*1*	*0*	*1*	*0*																			*3*
August 11-12																												
40			2	15	25	18	13	16	23	24	8	15	10	3	3	6	31	10	6	4	8					6	240	
			3	*3*	*4*	*2*	*3*	*3*	*2*	*5*	*2*	*2*	*2*	*0*	*2*	*4*	*4*	*2*	*1*	*2*	*1*							*47*
44			0	5	7	1	3	5	3	1	1	1	1	6	5	9	2	5	1	1						3	57	
			2	*3*	*0*	*3*	*1*	*3*	*3*	*1*	*0*	*1*	*0*	*6*	*2*	*7*	*1*	*1*	*3*	*1*								*39*
34								15	30	31	29	27	18	24	8											8	182	
								6	*7*	*3*	*7*	*10*	*5*	*5*	*0*													*43*
12									4	7	2	3	6	3												2	25	
									6	*6*	*1*	*1*	*2*	*0*														*16*

TABLE I (*continued*)

E.S.T.	h8	9				10				11				12				1				2				3				4		No. of	Totals	
Group No.	m30	50	10	30	50	10	30	50	10	30	50	10	30	50	10	30	50	10	30	50	10	30	50	10	30	50	10	30	50	10	30	Observers	Perseids	Non-Perseids
August 11-12																																		
10			3	3	2	3	7	6	5	6	8	4	3	4																		2	54	
			0	*0*	*0*	*1*	*1*	*1*	*1*	*1*	*0*	*0*	*1*	*6*																				*6*
13							7	6	2	5	3	3	8	6	3																	1	43	
							2	*0*	*0*	*0*	*1*	*0*	*0*	*1*	*0*																			*4*
14								2	12	8			8	16	17	24	21	24	15													3	147	
								2	*1*	*1*			*1*	*5*	*1*	*3*	*1*	*3*	*6*															*24*
27			1	2	1	2	2	4	1	1	1	0																				1	15	
			1	*1*	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*1*																						*4*
28		2	5	6	4	11	7	15	9	7				5	14	13	9	9	6	5												3	127	
		0	*2*	*1*	*1*	*2*	*3*	*1*	*5*	*1*				*2*	*2*	*1*	*4*	*3*	*5*	*2*														*35*
29															1	6	15	26	31	31	15	12	10	2								2	149	
															1	*1*	*4*	*7*	*4*	*5*	*3*	*3*	*3*	*1*										*35*
9																	2	9	9	7	6	6										1	39	
																	0	*0*	*2*	*0*	*2*	*0*												*4*
16												2	14	9			7	9	1	0												3	42	
												0	*2*	*1*			*2*	*3*	*0*	*2*														*10*
18									3	1	5	10	4		3			2	3	4	5	4										3	44	
									1	*1*	*2*	*2*	*2*		*3*			*1*	*2*	*1*	*0*	*1*												*16*
1								2	11	15	8	19																				2	55	
								1	*4*	*1*	*2*	*5*																						*13*
4									3	2	8	12	17	16																		2	58	
									1	*1*	*1*	*1*	*6*	*4*																				*14*

TABLE I (*continued*)

E.S.T.	h8	9			10			11			12			1			2			3			4			No. of	Totals	
Group No.	m30	50	10	30	50	10	30	50	10	30	50	10	30	50	10	30	50	10	30	50	10	30	50	10	30	Observers	Perseids	Non-Perseids
August 11-12																												
5				0	7	6	5	6	7	10	9	5	4	1	5	1	5									1	71	
				2	4	1				0			3	11	10	2	8											36
30				1	0	0				2			2	1	4	0	1									2	41	
									5	3																		11
38									1	1																1	8	
					1	6	2	4					1															2
31					2	2	1	1					0													1	14	
							1	5	8																			6
2							2	2	1																	1	14	
					1	2	2	3	0	3	1																	5
6					0	0	0	0	1	2	0															1	12	
										6	10	21	4	25	36	17	4											3
7										2	2	3	0	3	6	3	0									2	123	
																												19
32				1			1	1																		1	3	
								1	10	10	1	7	1	0	7	5												1
37								0	0	3	2	1	1	1	1	1										2	32	
								1	12	2	4	1																9
19								0	0	2	3	0														1	20	
									2	3	1	1																5
20								2	3	1	1															1	7	
								0	1	0	1																	2
22				1	1	1																				1	3	
				0	0	0																						0

TABLE I (*continued*)

E.S.T.	h8 m30	50	9 10	30	50	10 10	30	50	11 10	30	50	12 10	30	50	1 10	30	50	2 10	30	50	3 10	30	50	4 10	30	No. of	Totals	
Group No.																										Observers	Perseids	Non-Perseids
August 11-12																												
23			3		3	1																				1	7	
			0		2	3																						5
24			4	2	5	6	2																			1	19	
			0	0	2	0	0																					2
26							5	1																		1	6	
							0	0																				0
August 12-13																												
40					6	8	10	15	30	34	28	35	44	26	41	37	29	13	12	15	6	0	16	20		9	425	
					2	8	6	11	10	11	5	14	6	8	5	8	9	1	5	0	1	1	3	6				120
35																2	2	6	5	4	5	12	4			2	40	
																2	3	1	5	3	2	4	0					20
37			1				3	4	3	4	0															1	15	
			0				2	0	2	1	1																	6
44				3	2	5	6	6	4	8	8	10	17	16	14	15	17	16	16	1	10	19	18	5		3	215	
				1	2	0	2	3	4	1	1	3	4	5	8	1	4	3	2	0	5	6	3	6				59
36													1	3												1	4	
													1	0														1
12													5	7	9	6	9	15	11	14	13	19	8			1	116	
													4	3	5	11	7	2	4	8	7	6	3					61
29							1	10	8	7	7	3	6													2	42	
							1	1	2	3	0	2	2																11
30			1	4	5	4	8	9	9	11	2	2			12	14	10	12	7	6						2	114	
			0	1	2	3	4	2	3	2	2				0	0	4	1	1	1								26

TABLE I (*continued*)

E.S.T.	h8 m30	50	9 10	30	50	10 10	30	50	11 10	30	50	12 10	30	50	1 10	30	50	2 10	30	50	3 10	30	50	4 10	30	No. of Observers	Totals Perseids	Non-Perseids
Group No.																												
August 12-13 31				3 0	2 3	3 0																					1	8	3
10			1 0	0 0	1 0	1 0	1 0	2 0	3 1	2 1	1 0	2 0	1 1	6 1	3 0	3 1	3 0	3 0									1	33	5
11										7 0																	1	7	0
15															3 0	5 0	4 5	7 1									1	19	6
6						1 0	5 0	5 0	4 0																		1	15	0
7										2 1	2 1	0 0	9 3	12 6	21 9	9 3	10 5	2 1									2	67	29
8			7 1																								1	7	1
16		0 0	4 1	2 1	3 0																						1	9	2
17						2 0		0 1	2 0		0 1																1	4	2
18						2 0	4 0	3 2	1 3				5 0	4 1	0 3	2 0											1	21	9
19						2 1	2 0	2 1	2 0	0 0	3 1	1 0															1	12	3

TABLE I (*continued*)

E.S.T.	h8 m30	50	9 10	30	50	10 10	30	50	11 10	30	50	12 10	30	50	1 10	30	50	2 10	30	50	3 10	30	50	4 10	30	No. of	Totals	
Group No.																										Observers	Perseids	Non-Perseids
August 12-13 20									1 *2*	4 *1*																1	5	*3*
23			3 *0*			1 *0*	3 *0*																			1	7	*0*
25					2 *1*	1 *0*																				1	3	*1*
27	1 *1*	1 *1*	2 *0*	2 *0*	1 *0*	0 *0*	1 *0*																			1	8	*2*
4							2 *1*	9 *3*	5 *2*	5 *1*	9 *3*	6 *1*														2	36	*11*
August 13-14 3								1 *0*																		1	1	*0*
11								5 *1*	2 *0*	4 *0*																1	12	*1*
21				1 *0*	3 *1*	2 *1*																				1	6	*2*
30										4 *0*	1 *3*															2	5	*3*
33											1 *0*	1 *1*	0 *1*	1 *1*	1 *1*	1 *0*	0 *1*	1 *0*								1	6	*5*
																										Totals	4131	1367

(Non-Persides in Italics)

following. The rate rose to about 100 Perseids an hour on Aug. 10-11. On Aug. 11-12 rates up to 150 an hour were observed where it was clear. At the Dunlap Observatory it was partially cloudy all night. Some meteors were seen above the clouds when no

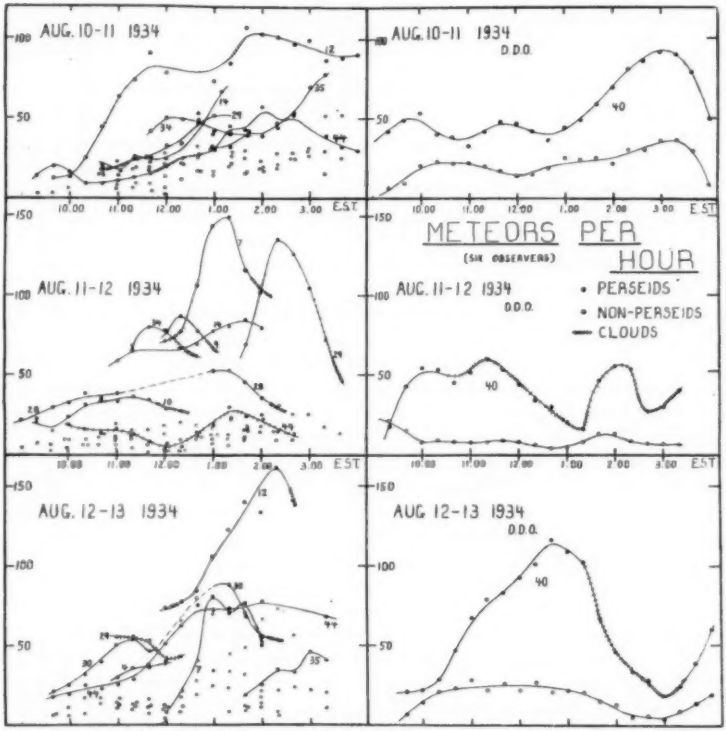

FIG. 1.—Hourly Rates of the Perseid Meteors. The numbers near the curves correspond to the numbers in the list of observation groups.

stars were visible. There seemed to be almost as many meteors on Aug. 12-13 though clouds again spoiled the last part of the night. The rate of 160 an hour for group 12 on this night may not be comparable with the others as it was derived from a single observer and the Non-Perseids for this same group are abnormally high,

TABLE II

MAGNITUDE DISTRIBUTION OF THE METEORS

Mag.	−6	−5	−4	−3	−2	−1	0	1	2	3	4	5	6	Totals	Mean Mag.
D.D.O. Perseids			6	5	17	50	111	209	310	221	89	19	..	1037	1.76
D.D.O. Non-Perseids				1	2	8	20	52	83	86	53	7		312	2.30
Others Perseids	1	1	1	13	29	86	219	548	785	694	276	80	7	2740	2.02
Others Non-Perseids			1	5	11	17	52	155	273	238	135	30	4	921	2.25

which would indicate that the reduction factor used did not apply in this particular case. The Perseids, however, were most certainly more numerous on Aug. 12-13 than they were on Aug. 10-11.

Magnitudes were estimated for 4010 meteors. The magnitude distributions for all but the Dunlap Observatory group and also

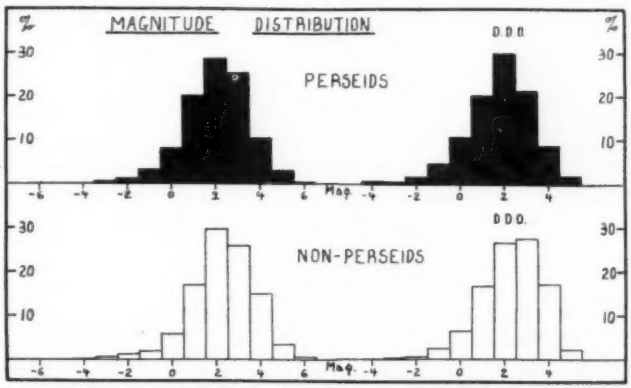

FIG. 2.—Magnitude Distribution of Meteors observed on the Perseid Programme.

for this group alone are given in Table II and plotted in percentages in Figure 2. The magnitude distributions for the Dunlap Observatory differ from the others in that they contain no duplicate meteors. Over 95 per cent. of the meteors here reported were plotted on the maps. These observations have thus produced a large amount of

material for the computation of heights and this is now being studied and reduced. No remarkable enduring trains were observed though many lasting from three to ten seconds were noted.

The writer would like to express his thanks to all those who coöperated in making this the most successful program of meteor observations yet undertaken in Canada.

P. M. M.

MEETINGS OF THE SOCIETY

AT TORONTO

May 8, 1934.—The meeting was held at 8.00 p.m., in the University of Toronto; Mr. R. A. Gray in the chair.

The following candidates were elected to membership in the Society:

Mr. Charles S. Gulston, B.A., 55 Hammersmith Avenue, Toronto.

Mr. Thos. E. Coupe, R.R. 1, Allandale, Ontario.

Mr. A. E. Prince, 2a Graham Street, Copper Cliff, Ont.

Mr. S. W. John, Jr., Loomis School, Windsor, Conn.

Mr. J. Wesley Simpson, 639 Locksley Place, Webster Groves, Missouri.

Mr. N. V. Carlson, (P.O. Box 1636), Manila, P.I.

The last three are members-at-large.

Miss E. M. Budd, assistant librarian, reported that in addition to the usual technical publications received from all parts of the world, a number of new popular books had been recently added to the library and were available to members.

Astronomical phenomena for the summer months were outlined by F. L. Troyer. E. J. A. Kennedy and J. R. Collins commented on the "white spot', on Jupiter, and other members reported recent observations.

The chairman announced that the usual annual out-door observation meeting would take place on Tuesday, May 22, weather permitting, when telescopes would be placed on the University campus and the six-inch refractor of the University would be available for the use of members.

Mr. H. G. Duncalfe then provided an interesting description and demonstration of a unique type of sundial which he had constructed. In this instrument a thin metal wire replaces the usual gnomon, and a small metal bead located on the wire casts the shadow. From the instrument might be read, not only the time of day, which Mr. Duncalfe said might readily be ascertained to the minute, but also the equation of time, the declination of the sun, the approximate length of day and night, and the direction of rising and setting of the sun for any day in the year.

Mr. A. F. Miller, a charter member and past president of the Society then addressed the meeting on "The Founding and Incorporation of the Royal Astronomical Society of Canada."

Mr. Miller who was until a few years ago a familiar and prominent figure in the life of the Society, provided a brilliant account of the early days of the organization, which was interspersed with interesting reminiscences of the men who were responsible for the formation of the Astronomical and Physical Society of Toronto, which was later to become the Royal Astronomical Society of Canada. A sure and strong foundation had been laid by Mr. Andrew Elvins who had long taken an active interest in astronomy and had gathered around him a group of

Toronto laymen who had through his efforts become interested in the subject. Mr. Miller, who had met Mr. Elvins in 1881, became a member of the informal group, which later was known as the Toronto Astrophysical Society and met on Tuesday evenings at Mr. Elvins' or Mr. Miller's home. In 1887, Mr. Miller introduced Mr. George E. Lumsden, then assistant provincial secretary, into the group, and in 1890, largely at Mr. Lumsden's suggestion, it was decided to incorporate the Society as the Astronomical and Physical Society of Toronto. The membership and scope of the Society soon became national and the name was changed in 1900 to the Toronto Astronomical Society, and in 1903, again at Mr. Lumsden's suggestion and through the good offices of Sir Joseph Pope, then Under-secretary of State for Canada, permission was obtained from His Majesty, King Edward VII, to assume the name, "The Royal Astronomical Society of Canada."

The charter members, in addition to Messrs. Elvins, Lumsden and Miller, were Mr. Charles Carpmael, M.A., F.R.S.C., F.R.A.S., director of the Toronto Observatory; Mr. David Howell, a photographer, now living in England; and Mr. G. G. Pursey. Mr. Carpmael was the first president of the Society after its incorporation.

Mr. A. F. Hunter for a number of years previous to incorporation had, as a student in Toronto, taken an active part in the meetings of the informal group but was not included in the charter membership as at the time he was living in Barrie where he was instrumental in forming a local astronomical club. Mr. Miller mentioned many others who were well known in the work of the Society but were not actual charter members.

The thanks of the audience were conveyed to Mr. Miller by Dr. C. A. Chant. The meeting then adjourned.

FREDERIC L. TROYER, *Acting Recorder.*

NOTICE TO MEMBERS OF THE VICTORIA CENTRE

Will the members having the following books from the Library of the Victoria Centre kindly return them as soon as possible.

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SIR RICHARD GREGORY:—Discovery, or, the Spirit and Service of Science.
NATIONAL RESEARCH COUNCIL (U.S.A.):—Introductory Meteorology.
RICHARD A. PROCTOR:—Other Worlds than Ours.
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D. ARCHIBALD:—The Story of the Atmosphere.
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